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UTILITY PATENT APPLICATION TRANSMITTAL

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Attorney Docket No.	MI22-981
Total Pages	27
First Named Inventor or Application Identifier	Warren M. Farnworth et al
Express Mail Label No.	EL169834996US

65705 U.S. PTO 09/148723 09/03/98

jc525 U.S. PTO

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

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1. [ ] Fee Transmittal Form (Submit an original, and a duplicate for fee processing)
2. [X] Specification [Total Pages 20] + cover sheet (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) (35 USC 113) [Total Sheets 3]
4. Oath or Declaration [Total Pages 2]
   a. [X] Newly executed (original or copy) ~~Newly~~ Executed
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed) [Note Box 5 below]
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
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6. [ ] Microfiche Computer Program (Appendix)
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ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
10. [ ] English Translation Document (if applicable)
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
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PATENT 08054.0996

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

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Methods Of Bonding Solder Balls To Bond Pads On A Substrate, And Bonding Frames

* * * * *

INVENTORS

Warren M. Farnworth
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ATTORNEY'S DOCKET NO. MI22-981

EL169834996

METHODS OF BONDING SOLDER BALLS TO BOND PADS ON A SUBSTRATE, AND BONDING FRAMES

TECHNICAL FIELD

The present invention relates to methods of bonding solder balls to bond pads on a substrate, and to bonding frames.

BACKGROUND OF THE INVENTION

As integrated circuitry becomes smaller and more dense, needs arise relative to the packaging and interconnecting of fabricated integrated circuitry devices. Concerns associated with increasing the speed with which integrated circuitry devices are packaged and the efficiency with which the devices are packaged drive the industry to find faster and more flexible systems and methods for packaging integrated circuitry. Specifically, one aspect of integrated circuitry packaging includes bonding conductive balls or solder balls on bond pads of a substrate for subsequent connection to packaging structure. Such is commonly referred to as solder ball bumping.

In the formation of solder-bumped substrates, solder ball material is provided over bond pads of a substrate supporting integrated circuitry thereon. If the substrates are to be flip-chip bonded to another substrate, it is important that the solder balls be of uniform size. Otherwise, some of the balls might not make desirable contact with the bond pads of the substrate to which it is to be bonded. This problem led to development of pre-formed solder balls which are formed to a

specific common tolerance dimension such that all of the solder balls are essentially the same size. Hence, when the solder balls are bonded by solder melting/welding to substrates, each will essentially project from the outer substrate surface a common distance and accordingly make contact with all bond pads when being bonded.

This invention arose out of concerns associated with providing improved methods and apparatuses for packaging integrated circuitry.

SUMMARY OF THE INVENTION

Methods and apparatuses for bonding solder balls to bond pads are described. In one embodiment, portions of a plurality of solder balls are placed within a frame and in registered alignment with individual bond pads over a substrate. While the ball portions are within the frame, the balls are exposed to bonding conditions effective to bond the balls with their associated bond pads. In another embodiment, a frame is provided having a plurality of holes sized to receive individual solder balls. Individual balls are delivered into the holes from over the frame. The balls are placed into registered alignment with a plurality of individual bond pads over a substrate while the balls are in the holes. The balls are bonded with the individual associated bond pads. In another embodiment, a frame is provided having a hole. A solder ball is provided having an outer surface. The solder ball is retained within the hole in an ambient processing environment which is generally uniform over the entirety of the ball's

outer surface. While the solder ball is within the hole, the solder ball is bonded with an associated bond pad on a substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a side elevational view of a portion of a frame which is disposed in a position to receive one or more solder balls in accordance with one or more embodiments of the present invention.

Fig. 2 is a side elevational view of a portion of a frame which is disposed in a position to receive one or more solder balls in accordance with one or more embodiments of the present invention.

Fig. 3 is a side elevational view of a portion of a frame which is disposed in a position to receive one or more solder balls in accordance with one or more embodiments of the present invention.

Fig. 4 is a side elevational view of a frame engaged with a substrate in accordance with one or more embodiments of the invention. A portion of the frame has been broken away to show detail.

Fig. 5 is a view of the Fig. 4 frame undergoing processing in accordance with one embodiment of the invention.

Fig. 6 is a view of the Fig. 4 frame undergoing processing in accordance with one embodiment of the invention.

Fig. 7 is a view of the Fig. 4 frame and substrate after the solder balls have been bonded with their individual associated bond pads.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

Referring to Fig. 1, a portion of a frame in accordance with one embodiment of the invention is shown generally at 10 and includes an outer surface 12 having at least one, and preferably a plurality of holes 14 therein. Holes 14 are preferably sized to receive individual solder balls 16 having individual solder ball outer surfaces 18. In one embodiment, the frame and holes are dimensioned to permit one and only one solder ball to be received within each hole at a time. In a preferred embodiment, a majority portion of an associated solder ball is received within each hole.

The solder balls can be provided into frame-supported positions in a variety of ways. In one embodiment, individual solder balls 16 are delivered into holes 14 from over frame 10, as Fig. 1 implies. In another embodiment (Fig. 2) a plurality of solder balls 16 are provided over surface 12, at least some of which being deposited into at least some of holes 14. The balls can be provided over the surface in any manner. In the illustrated example, balls 16 are provided over

surface 12 by rolling at least one, and preferably a plurality of the balls over the surface and into individual respective holes 14. The balls can be rolled over the frame surface until individual balls drop into individual associated holes. Alternately considered, frame 10 positioned in proximity to a substrate (not shown) to which conductive balls are to be bonded can be dipped into a volume of balls. Thereafter, the frame and substrate are removed from the volume of balls, with individual balls be received in respective frame holes. The balls are preferably small enough to pass through the holes.

Referring to Fig. 3, and in accordance with another embodiment of the invention, more solder balls 16 are provided than there are holes in outer surface 12. In this example, three solder balls 16 are provided for the two illustrated holes 14. One of the balls and the frame is moved relative to the other of the balls and the frame effective to deposit a ball into each hole. In this example, balls 16 are moved over surface 12 effective to deposit one solder ball into each hole. Excess solder balls, such as the leftmost solder ball 16, which were not deposited into a hole are removed from over surface 12. Removal of excess balls can be effected in any suitable way. Alternately considered, frame 10 positioned in proximity to a substrate (not shown) to which conductive balls are to be bonded can be dipped into a volume of balls. Thereafter, the frame and substrate are removed from the volume of balls, with individual balls be received in respective frame holes.

Referring to Fig. 4, frame 10 is shown in proximity with a substrate 20 having thereon a plurality of bond pads 22. Holes 14 hold one individual solder ball respectively, in registered alignment with an associated bond pad 22 on substrate 20. In one embodiment, each solder ball 16 is placed on a fluxless bond pad surface. Fluxless bond pad surfaces are preferably used in this embodiment because the frame maintains each individual solder ball in registered alignment with an associated bond pad prior to and during solder ball bonding described below. This embodiment can overcome some problems presented through the use of flux on bond pads. Specifically, flux will typically have to be completely cleaned from a substrate after the bonding process. This embodiment can permit the post-bonding cleaning step to be eliminated thereby simplifying the bonding process.

This embodiment also permits at least two solder balls 16 to be contemporaneously retained over different respective bond pads on substrate 20. In a preferred embodiment, frame 10 is moved to proximate substrate 20 before any of the balls are delivered into the holes. Subsequently, individual balls can be provided or delivered into the holes as described above.

In another embodiment, the solder balls are retained within each hole in an ambient processing environment which is generally uniform over the entirety of each ball's outer surface 18. Specifically, while each ball is retained within its associated hole and in registered alignment with an associated bond pad, the processing environment

outwardly of each ball is generally uniform. That is, retaining each ball within its respective hole can take place without the use of any outside environment-changing conditions such as vacuum pressure and the like on only a portion of the respective balls. The balls are preferably inserted into their associated hole from a position within the ambient processing environment without separately and discretely providing a vacuum force against only portions of each ball during bonding. Such non-vacuum retention provides more flexibility and increases the simplicity with which the balls can be processed.

Once having been placed in proximity with their individual associated bond pads, the individual solder balls can be bonded with their bond pads. The balls can be bonded separately, or can be bonded all at once as through suitable heat processing. Such can take place in any suitable manner, with but two examples being described below in connection with Figs. 5 and 6.

Referring to Figs. 5 and 6, solder balls 16 are exposed to bonding conditions effective to bond the balls with their associated bond pads 22. In one embodiment, the solder balls are reflowed under such bonding conditions while they are within their individual holes. For example, the two leftmost balls in Fig. 5 and the three rightmost balls in Fig. 6 are seen to have been reflowed while within their individual holes. In a preferred embodiment, a laser-bonding system 24 is provided and solder balls 16 are laser-bonded with their associated bond pads.

In one laser-bonding embodiment (Fig. 5), laser bonding is effected by fixing the position of frame 10 and moving a laser beam 26 relative to the frame from ball-to-ball. In this way, a laser beam is moved relative to and between individual balls to engage each ball.

In another laser-bonding embodiment (Fig. 6), laser bonding is effectuated by fixing the position of a laser beam 26 and moving frame 10 relative to the laser beam from ball-to-ball. In this example, frame 10 is moved in the direction of the arrow immediately below substrate 20. Accordingly, the three rightmost solder balls 16 have been reflowed by laser 26 while the four leftmost solder balls remain to be processed. Such comprises moving individual solder balls relative to a generally-fixed laser beam.

Referring to Fig. 7, frame 10 is moved away from proximity with substrate 20. Preferably, frame 10 is moved away from substrate 20 after individual solder balls are exposed to the bonding conditions. In this example, the holes are preferably dimensioned so that they do not overly restrict removal of the frame after the balls are reflowed. Accordingly, such comprises removing individual holes from around their associated reflowed balls. Of course, the frame could be moved away from the substrate prior to the exposure of the balls to the bonding conditions, particularly if flux or some other agent or means is used to retain the balls on their pads during bonding.

In another aspect of the invention, a frame is provided having a plurality of ball-supporting features which maintain at least two balls in

registered alignment with a substrate having bond pads thereon. In a preferred embodiment, the ball-supporting features comprise individual holes which extend through the frame and which are dimensioned to receive only one ball at a time. The holes are preferably disposed over the frame in a template-like orientation which matches the orientation of bond pads with which the solder balls are desired to be bonded. The inventive frames can enable a large number of solder balls to be simultaneously placed into bond pad-engaging positions where they can be subsequently bonded in a time-saving fashion.

Aspects of the invention enable solder balls to be placed with greater precision and in greater numbers than was previously possible. Such enables throughput to be increased and provides for better integrated circuitry packaging uniformity. In addition, solders balls can be placed and bonded in greater numbers on fluxless bond pads which can increase throughput by expediting processing.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

CLAIMS:

1. A method of bonding solder balls to bond pads on a substrate comprising:

contemporaneously retaining at least two solder balls over different respective bond pads on a substrate in the absence of flux; and

with said balls so retained, exposing the balls to bonding conditions effective to bond the balls with their associated bond pads.

2. The method of claim 1, wherein the exposing of the balls comprises laser-bonding the balls.

3. A method of bonding solder balls to bond pads on a substrate comprising:

placing at least portions of a plurality of solder balls within a frame and in registered alignment with individual bond pads over a substrate; and

while the ball portions are within the frame, exposing the balls to bonding conditions effective to bond the balls with their associated bond pads.

4. The method of bonding solder balls of claim 3, wherein said placing comprises placing individual solder balls within individual holes within the frame.

5. The method of bonding solder balls of claim 3, wherein said placing comprises placing majority portions of individual solder balls within individual holes within the frame.

6. The method of bonding solder balls of claim 3, wherein said exposing comprises laser bonding the balls with their associated bond pads.

7. The method of bonding solder balls of claim 3, wherein said exposing comprises laser bonding the balls with their associated bond pads by fixing the position of the frame and moving a laser beam relative to the frame from ball-to-ball.

8. The method of bonding solder balls of claim 3, wherein said exposing comprises laser bonding the balls with their associated bond pads by fixing the position of a laser beam and moving the frame relative to the laser beam from ball-to-ball.

9. The method of bonding solder balls of claim 3 further comprising moving the frame away from the substrate.

10. The method of bonding solder balls of claim 3 further comprising after the exposing of the balls, moving the frame away from the substrate.

11. The method of bonding solder balls of claim 3, wherein:

said placing comprises placing individual solder balls within individual holes within the frame; and

said exposing of the balls comprises reflowing the solder balls while the balls are within their individual holes, and further comprising after said reflowing removing the frame from around the reflowed balls.

12. The method of bonding solder balls of claim 3, wherein said placing comprises placing said ball portions on fluxless bond pad surfaces.

13. A method of bonding solder balls to bond pads on a substrate comprising:

providing a frame having a plurality of holes sized to receive individual solder balls;

delivering individual balls into the holes from over the frame;

placing the balls into registered alignment, while the balls are in the holes, with a plurality of individual bond pads over a substrate; and

bonding the balls with their individual associated bond pads.

14. The method of claim 13, wherein the holes are sized to receive a majority portion of an associated solder ball.

15. The method of claim 13, wherein the holes are sized to receive a majority portion of only one associated solder ball.

16. The method of claim 13, wherein said delivering of the individual balls comprises rolling at least one ball over a frame surface until the one ball drops into an associated hole.

17. The method of claim 13, wherein said delivering of the individual balls comprises rolling a plurality of balls over a frame surface until individual balls drop into respective associated individual holes.

18. The method of claim 13, wherein said placing of the balls into registered alignment comprises moving the frame to proximate the substrate before any of the balls are delivered into the holes.

19. The method of claim 13, wherein said placing of the balls into registered alignment comprises moving the frame to proximate the substrate before any of the balls are delivered into the holes; and

said delivering of the individual balls comprises rolling a plurality of balls over a frame surface until individual balls drop into respective associated individual holes.

20. The method of claim 13, wherein the bonding of the balls comprises laser bonding the balls with their individual associated bond pads.

21. The method of claim 13, wherein the bonding of the balls comprises laser bonding the balls with their individual associated bond pads by fixing the position of the frame and moving a laser beam relative to the frame from ball-to-ball.

22. The method of claim 13, wherein the bonding of the balls comprises laser bonding the balls with their individual associated bond pads by fixing the position of a laser beam and moving the frame relative to the laser beam from ball-to-ball to effectuate the bonding.

23. A method of bonding solder balls to bond pads on a substrate comprising:

providing a frame having a plurality of holes;

inserting individual solder balls into the holes, the balls being small enough to pass through the holes;

placing the frame into proximity with a substrate having bond pads positioned thereon, more than one of the plurality of holes holding an individual solder ball therewithin and in registered alignment with an associated bond pad on the substrate;

laser-bonding the solder balls to their individual bond pad; and

after the laser bonding, removing the frame from proximity with the substrate.

24. The method of claim 23, wherein said inserting comprises inserting said balls from over the frame.

25. The method of claim 23, wherein said laser-bonding comprises moving a laser beam relative to and between individual solder balls.

26. The method of claim 23, wherein said laser-bonding comprises moving individual solder balls relative to a generally-fixed laser beam.

27. A method of bonding a solder ball to a bond pad on a substrate comprising:

providing a frame having a hole;

providing a solder ball having an outer surface;

retaining the solder ball within the hole in an ambient processing environment which is generally uniform over the entirety of the ball's outer surface; and

while the solder ball is within the hole, bonding the solder ball with an associated bond pad on a substrate.

28. The method of claim 27, wherein the retaining of the solder ball comprises retaining at least a majority portion of said ball within the hole.

29. The method of claim 27 further comprising inserting the ball into the hole from a position within said ambient processing environment.

30. The method of claim 27, wherein the bonding of the solder ball comprises laser bonding said ball.

31. A method of bonding solder balls to bond pads on a substrate comprising:

providing a surface having a plurality of holes therein;

providing a plurality of solder balls over the surface;

depositing some of the solder balls into at least some of the holes; and

bonding the solder balls which were deposited into the holes to individual associated bond pads positioned on a substrate proximate the holes.

32. The method of claim 31, wherein the providing of the solder balls comprises rolling at least one ball over the surface and into a hole.

33. The method of claim 31, wherein the providing of the solder balls comprises rolling a plurality of balls over the surface and into individual respective holes.

34. The method of claim 31, wherein:

each hole is dimensioned to receive only one ball; and

the providing of the solder balls comprises rolling a plurality of balls over the surface and into individual respective holes.

35. The method of claim 31 further comprising removing any balls from over the surface which were not deposited into a hole.

36. The method of claim 31, wherein the bonding of the balls comprises laser-bonding each ball to an individual bond pad.

37. The method of claim 31, wherein the bonding of the balls comprises laser-bonding each ball to an individual bond pad by fixing the position of a laser beam and moving each ball into the path of the laser beam.

38. The method of claim 31, wherein the bonding of the balls comprises laser-bonding each ball to an individual bond pad by moving a laser beam to engage each ball.

39. A method of bonding solder balls to bond pads on a substrate comprising:

providing a surface having a plurality of holes therein;

providing more solder balls than there are holes over the surface;

moving the plurality of balls and the surface relative to one another effective to deposit one solder ball into each hole;

removing excess solder balls from over the surface; and

bonding the balls which were deposited into the holes to individual bond pads positioned on a substrate proximate the holes.

40. The method of claim 39, wherein the bonding of the balls comprises laser bonding the balls.

41. The method of claim 39, wherein the bonding of the balls comprises laser bonding the balls by moving each ball into the path of a laser beam.

42. A solder ball support apparatus comprising:

a frame; and

a plurality of ball-supporting features configured to maintain at least two solder balls in registered alignment with at least two different bond pads on a substrate.

43. The solder ball support apparatus of claim 42, wherein the ball-supporting features comprise individual holes which extend through the frame.

44. The solder ball support apparatus of claim 42, wherein the individual holes are dimensioned to receive only one solder ball at a time.

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ABSTRACT OF THE DISCLOSURE

Methods and apparatuses for bonding solder balls to bond pads are described. In one embodiment, portions of a plurality of solder balls are placed within a frame and in registered alignment with individual bond pads over a substrate. While the ball portions are within the frame, the balls are exposed to bonding conditions effective to bond the balls with their associated bond pads. In another embodiment, a frame is provided having a plurality of holes sized to receive individual solder balls. Individual balls are delivered into the holes from over the frame. The balls are placed into registered alignment with a plurality of individual bond pads over a substrate while the balls are in the holes. The balls are bonded with the individual associated bond pads. In another embodiment, a frame is provided having a hole. A solder ball is provided having an outer surface. The solder ball is retained within the hole in an ambient processing environment which is generally uniform over the entirety of the ball's outer surface. While the solder ball is within the hole, the solder ball is bonded with an associated bond pad on a substrate.

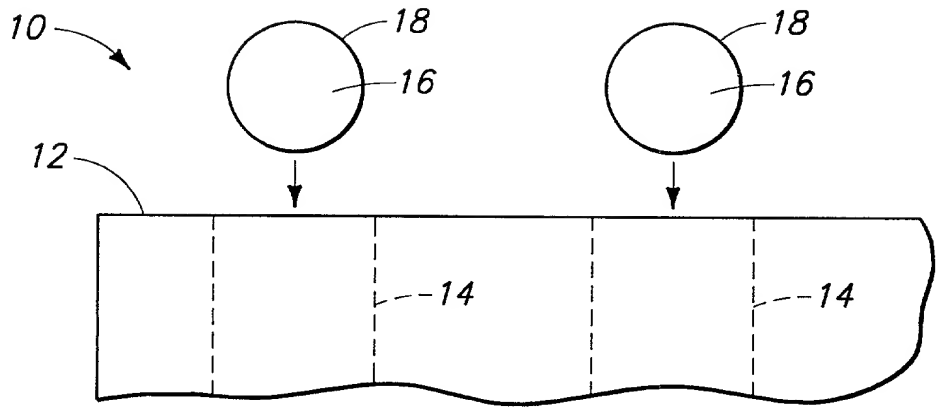

Fig 1

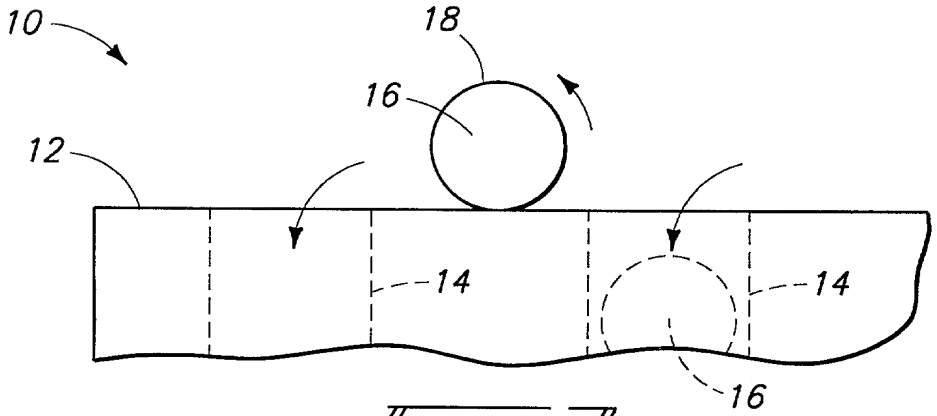

Fig 2

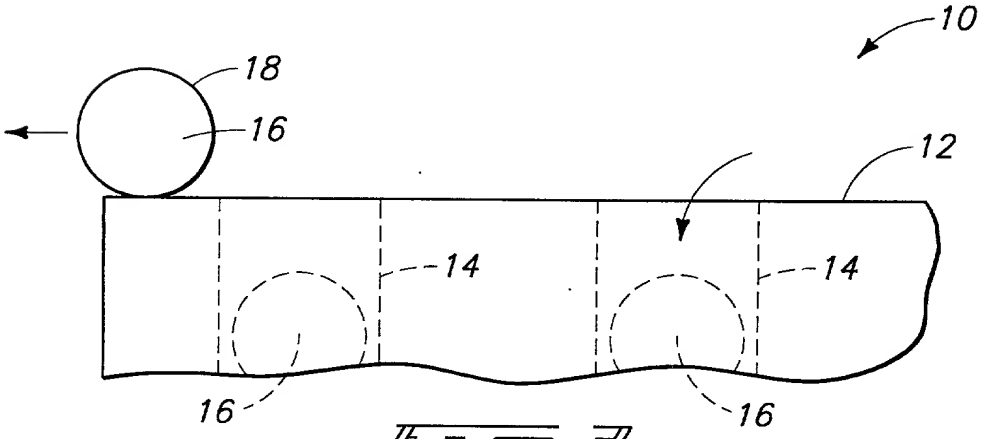

Fig 3

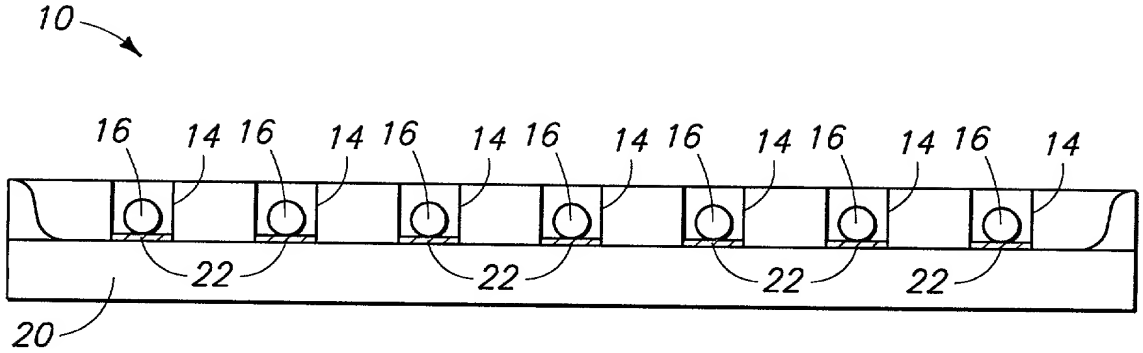
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Fig 4

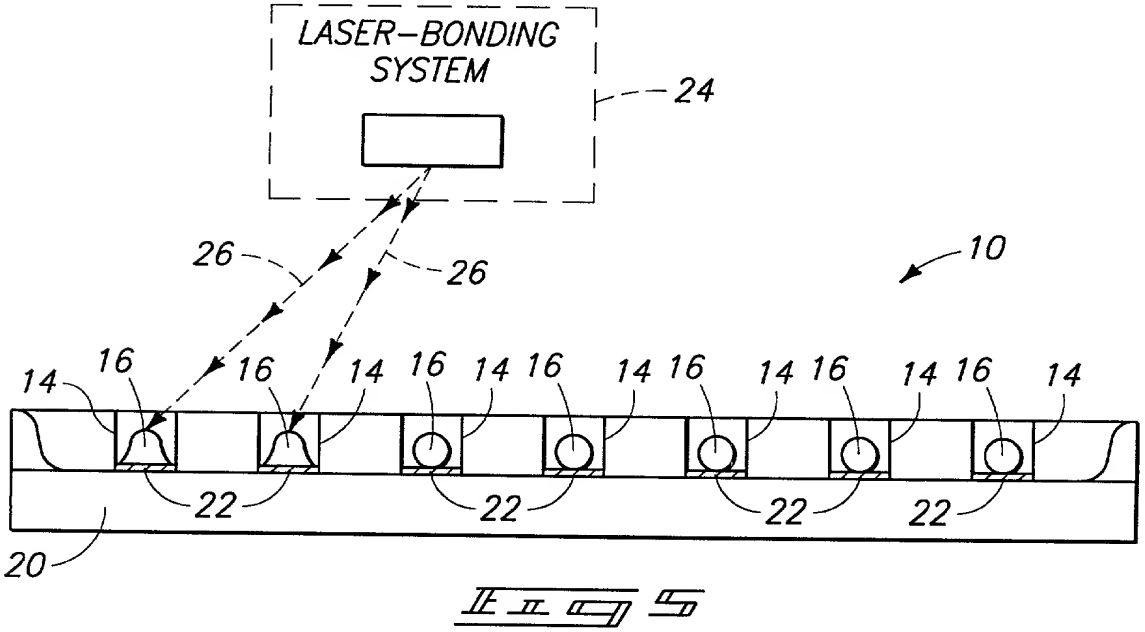
LASER-BONDING SYSTEM
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Fig 5

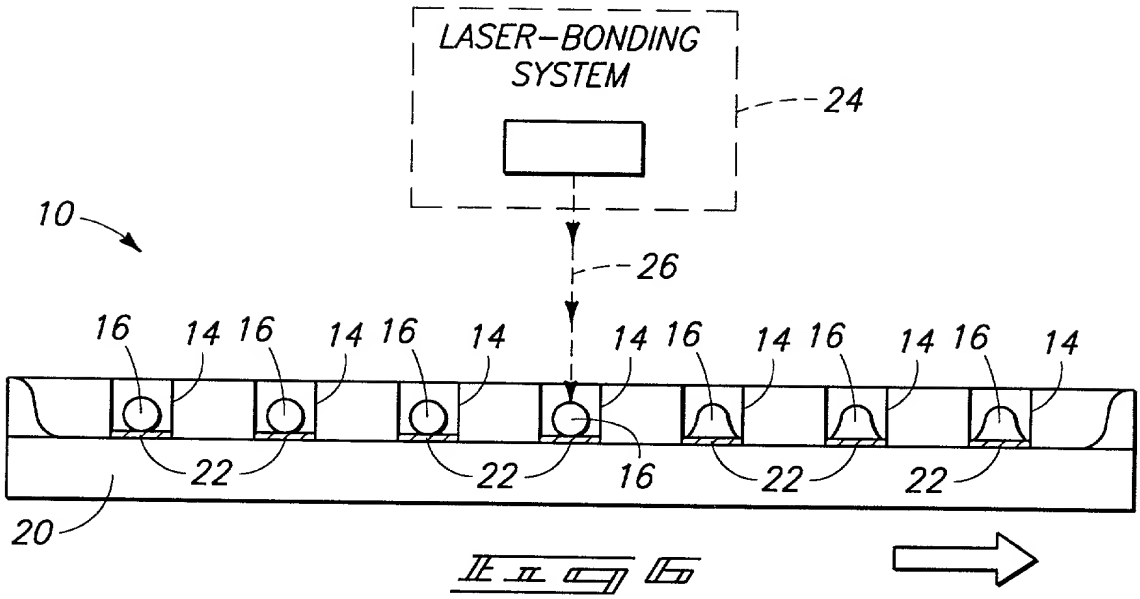

Fig 6

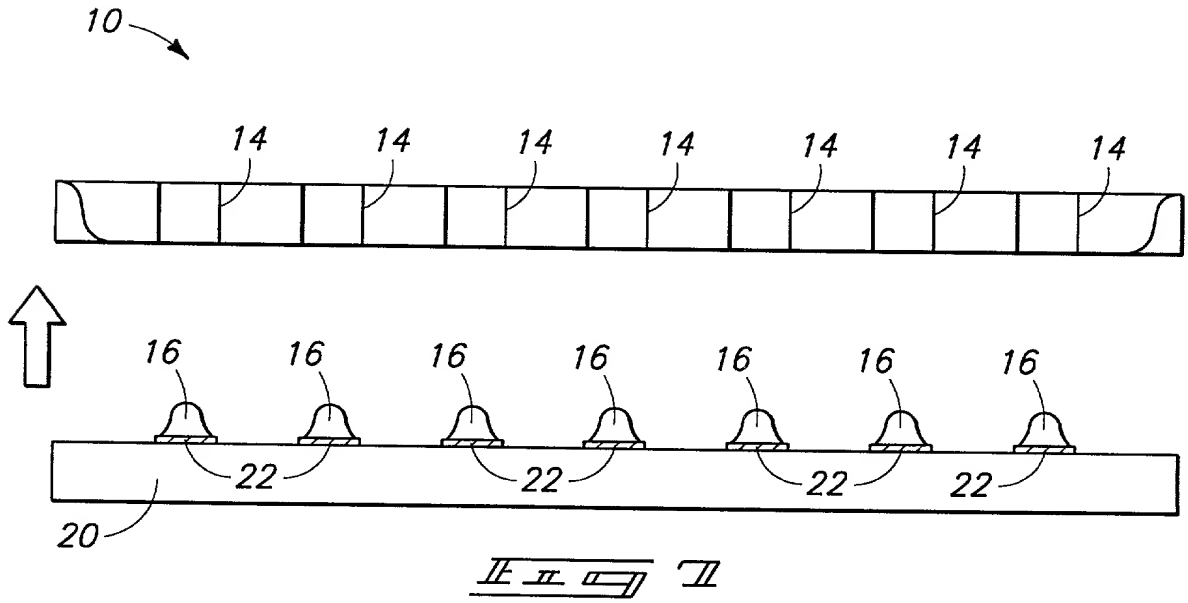

Fig 7

DECLARATION OF JOINT INVENTORS FOR PATENT APPLICATION

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: Methods of Bonding Solder Balls to Bond Pads on a Substrate, and Bonding Frames, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56.

PRIOR FOREIGN APPLICATIONS:

I hereby state that no applications for foreign patents or inventor's certificates have been filed prior to the date of execution of this declaration.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful

false statement may jeopardize the validity of the application or any patent issued therefrom.

* * * * * * * * * * *

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